

UNCLASSIFIED

AD NUMBER
AD848593
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM No Foreign
AUTHORITY
ODDR&E ltr, 6 Jan 71

THIS PAGE IS UNCLASSIFIED

AD848593

TRENDS
IN USAGE OF
RHENIUM

CB

DDO
RECEIVED
MAR 6 1969
ILLINOIS

MAB

TRENDS IN USAGE OF RHENIUM

REPORT

of the

**COMMITTEE ON TECHNICAL ASPECTS OF
CRITICAL AND STRATEGIC MATERIALS**

MATERIALS ADVISORY BOARD

DIVISION OF ENGINEERING - NATIONAL RESEARCH COUNCIL

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Office of the Director of Defense Research and Engineering (Chief, Materials Division, OADCT).

Publication MAB-251

National Research Council

National Academy of Sciences - National Academy of Engineering

Washington, D. C.

December 1968

This report is one of a series in a study undertaken by the Materials Advisory Board for the National Academy of Sciences in partial execution of work under Contract No. DA-49-083-OSA-3131 between the Department of Defense and the National Academy of Sciences. Additional financial support for this study was provided by the Office of Emergency Planning, General Services Administration and the Bureau of Mines through the Department of Defense.

As a part of the National Research Council, the Materials Advisory Board performs study, evaluation or advisory functions through groups composed of individuals selected from academic, governmental, and industrial sources for their competence or interest in the subject under consideration. Members of these groups serve as individuals contributing their personal knowledge and judgments and not as representatives of any organization in which they are employed or with which they may be associated.

No portion of this report may be republished without prior approval of the Materials Advisory Board.

Copies of this report are not available from the Clearinghouse for Federal Scientific and Technical Information (CFSTI). Qualified requesters may apply through Defense Documentation Center. Those who do not use the Defense Documentation Center may apply to the Materials Advisory Board.

**MATERIALS ADVISORY BOARD
COMMITTEE ON TECHNICAL ASPECTS OF CRITICAL & STRATEGIC MATERIALS**

Chairman: Dr. William A. Johnson, General Manager, TRW Equipment Labs., TRW, Inc., 23555 Euclid Avenue, Cleveland, Ohio 44117.

Members: Dr. John Convey, Director, Mines Branch, Department of Energy, Mines & Resources, 555 Booth Street, Ottawa, Canada.

Mr. David C. Goldberg, Manager, Materials Department, Astronuclear Laboratory, Westinghouse Electric Corporation, P. O. Box 10864, Pittsburgh, Pennsylvania 15236.

Dr. John C. Hamaker, Jr., President, Rodney Metals, Inc., 1357 E. Rodney French Boulevard, New Bedford, Massachusetts 02744.

Dr. N. B. Hannay, Executive Director, Research-Materials Division, Bell Telephone Laboratories, Inc., Murray Hill, New Jersey 07971.

Dr. Richard J. Lund, Senior Advisor, Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio 43201.

Dr. Robert J. Raudebaugh, Assistant to the Manager, Paul D. Merica Research Lab., The International Nickel Company, Inc., Suffern, New York 10901.

Dr. Hans Thurnauer, Technical Advisor, Coors Porcelain Company, 600 Ninth Street, Golden, Colorado 90401.

Mr. George J. Wile, Polymet Corporation, 11 West Sharon Road, Cincinnati, Ohio 45246.

Liaison Representatives:

Mr. Lloyd Eno, Research Coordinator, National Analysis Center, Office of Emergency Planning, Washington, D. C. 20504.

Dr. Earl T. Hayes, Acting Director, Bureau of Mines, Department of the Interior, Washington, D. C. 20240.

Mr. William Kaestner, Office of Metals & Minerals, Business & Defense Services Administration, Department of Commerce, Washington, D. C. 20230.

Mr. Harold Kirkemo, Assistant Chief, Office of Minerals Exploration, Geological Survey, Department of the Interior, Washington, D. C. 20240.

Mr. James W. Owens, Director, Office of Metals & Minerals, Business & Defense Services Administration, Department of Commerce, Washington, D. C. 20230.

Mr. Carl Rolle, Office of the Secretary of Defense Installations & Logistics, Room 2B322, The Pentagon, Washington, D. C. 20310.

Mr. J. Harold Stehman, National Resource Analysis Center, Office of Emergency Planning, Washington, D. C. 20504.

Mr. D. A. Woodard, Technical Advisor (Engineering), Marketing & Economics Division, General Services Administration, Wash., D. C. 20406.

Materials Advisory Board Staff:

Dr. Joseph R. Lane, Staff Metallurgist, National Research Council, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington, D. C. 20418.

Special acknowledgement and thanks are due Mr. David C. Goldberg, who prepared the draft report for the Committee's review and approval.

TABLE OF CONTENTS

	<u>Page</u>
Committee Membership.	iii
Abstract	vii
Availability	1
Background, References and Correspondence	6
Appendix A	7
Appendix B	9

ABSTRACT

Rhenium is a rare, expensive, high-melting metal with some unique properties, including a ductilizing effect on several brittle refractory metals. It occurs as an impurity in molybdenite which is associated, in small amounts, with copper ores. Production and consumption have been less than a ton per year, with the potential production, while substantially larger, still definitely limited. Research is disclosing probable valuable applications, leading to the recommendation that efforts to conserve rhenium for probable future applications should receive support.

RHENIUM

Availability

Rhenium does not occur as a distinct mineral species, but is, however, widely distributed in very minor amounts. It is from molybdenite (that which is associated with copper ores) that all current commercial rhenium is extracted. DMIC Memorandum 235 (March 1968) and the January 1968 Bureau of Mines "Commodity Data Summaries," reviewed the current supply situation in adequate detail. It is worth noting that the total world resources of rhenium from molybdenite is about 600 tons with an additional 290 tons from other ores.

The total maximum United States production potential is estimated between a low of 7,500 lb/year to a high of 30,000 lb/year. Mr. J. Maltz of NASA presented a table of production, capacity, consumption, and potential production.* His table (Ref. 1-6 on Page 2) shows a constant increase in production and consumption. Ref. 7 and 8 are in slight disagreement with the cited data. Additional data from other sources are incorporated into this table.

Imports of rhenium metal in 1967 were estimated at 11% of United States consumption, 8% in 1966, 46% in 1965, 14% in 1964, and 4% in 1963. One commercial fabricator foresees a 10% level for the near future.

Research and detailed evaluation of the physical and mechanical properties of the refractory metals and their alloys have received major support during the past decade because of the demanding requirements of the aerospace industry. Rhenium, because of its unique properties, has received a well-deserved share of this attention.

*Presented at the April 25-26, 1968 AIME Refractory Metal Conference in Washington, D. C.

TABLE I - PRODUCTION FIGURES ON RHENIUM (in lbs)

	<u>Production</u>	<u>Capacity</u>	<u>Consumption</u>	<u>Potential Production**</u>
1957	---	1800*	---	---
1958	---	---	---	---
1959	≈100*(1)	---	---	12000*(1)
1960	>200*(2, 4)	---	---	20-30000± (1)
1961	---	---	---	---
1962	1000*(5)	---	---	---
1963	1400*(2, 4)	---	≈ 500*(6)	---
1964	---	>5000*(4)	≈1500*(6)	28000(5, 6)
1965	≈ 2000*(6)	---	≈1600*(3)	---
1966	---	---	≈1200 (7)	---
1967	≈1200 (8) (9)	8000*(5)	---	≈ 12000 (8)

* United States

± Western World

** Added Facility Needed

References:

1. DMIC No. 19, May 1959
2. Port, Chase Brass, Plansee Meeting
3. Colorado School of Mines from Bureau of Mines Data 1965
4. Port, 1964 AIME Meeting
5. Spelman, Metals Progress, February 1968
6. Gonser, 1966 Gillette Lecture
7. "Commodity Data Summaries" United States Department of the Interior, Bureau of Mines, January 1966
8. DMIC Memo 235, March 1968
9. Bureau of Mines indicated 1967 production of 850 lbs due to the copper strike

This high density metal has a melting point exceeded only by tungsten, together with a high modulus of elasticity. Furthermore, it has a hardening effect on platinum, and a ductilizing effect on chromium, tungsten and molybdenum. Thermocouple systems yielding high emf's, which can operate at temperatures to at least 2400°C. are possible using alloys of rhenium with tungsten or molybdenum.

Because of high cost (\$630/lb for powder - \$1600/lb for mill product) and low industry production capability, few applications except high temperature thermocouples have had widespread commercial usage. However, in recent years a number of developments have taken place which appear to portend extended usage and possible additional production requirements for the metal, particularly if and when high temperature reactor technology and space electrical power systems are restored to the 1967 level of support. It is estimated that 75% of rhenium metal consumption is in research and development refractory metal alloy projects.

Among the new developments that should be mentioned are the structural alloys: tungsten RHC (4%Re-0.35%Hf-0.24%C) and ASTAR 811C (Ta-8W-0.7Hf-1.0Re-0.024C) and Ag-Re coating for pivot pins for a variable-wing aircraft. Historical applications for Re metal include igniters for flash lamps, electric furnace heaters, contacts for high current applications, vacuum tube filaments, cathodes, and cathode supports and heaters. These latter applications are estimated to consume about 25% of current production. It is known that rhenium is being considered for use as a catalyst in gasoline refinery operations but little specific data are available to estimate quantities.

Another large potential use of rhenium is in the recently developed nickel-base cast superalloy TRW-NASA VI A containing 0.3-0.5% Re which is currently under intensive investigation by the turbine engine manufacturers. This alloy developed under NASA sponsorship for jet engine turbine bucket applications

represents a substantial improvement of about 50°F over present-day high strength nickel-base superalloys. Experimental results have shown that the rhenium addition is necessary in maintaining the high temperature properties of the alloy. At the 0.3% Re level in this alloy, a possible annual consumption of 3,000 to 6,000 lbs of rhenium could be expected (blade weight: 1-2 lbs, 100 blades/engine, 1,000 engines/year). Since this consumption level of rhenium is three times the current use level, the developer is exploring reduced rhenium content compositions.

Under AEC sponsorship W-Re-Mo alloys have been developed which should find application in high temperature reactors which are coupled with thermionic devices. These alloys appear to have a good combination of fabricability and useful properties.

There is no definite indication of an immediate upswing in demand for rhenium for application as an alloying element, plating compound, or base metal. It is probable, with reduced AEC support in FY 1969 and 1970 of rhenium-alloy work, the demand will be below the 1,000 lb/year level. Industry can readily meet this requirement. However, it is strongly recommended that industry consider the stockpiling of rhenium-containing residues in view of probable increased future demand.

Since no element other than rhenium has demonstrated as strong a ductilizing effect on Mo, W, and Cr (a pronounced lowering of the ductile-to-brittle transition temperature) it is likely that when research support is re-established an increased demand for rhenium will be seen. It is estimated that this demand will still be below current industry capacity.

Rhenium substitutes as alloy constituents may be found among those elements such as Fe, Co, Ni, Tc, Ru, Rh, Os, Ir, and Pt which increase the Periodic Table Group Number above six. However, none so far have been an

adequate substitute for rhenium added singly or in combination. Further research is needed on rhenium substitutes in order to take full advantage of W, Mo, and Cr base alloys.

The recommendations of a NASA Research and Technology Advisory Committee on Materials, which has been studying this element will be of interest to the readers of this report. They are included with permission as Appendix A. We concur with the expressed need for continued research on this metal.

The number one recommendation of the MAB Panel on Rhenium (reported on Page 281 of MAB-154M, Report of the Committee on Refractory Metals, October 15, 1959) is pertinent and still appropriate. It is reproduced as Appendix B.

Summary and Recommendations

Rhenium is a scarce element, and the prospects for substantially increasing production do not appear to be bright. Modest requirements for rhenium have evolved from recent research activities, requirements which so far have not strained reserves or production capabilities. Since some important functions of the element (ductilizer for Cr, Mo, and W, strengthener in high temperature alloys, thermocouple elements) are practically unique, future demand can confidently be anticipated. Therefore the conservation such as by stockpiling, of rhenium (some of which is not recovered during molybdenum processing) should be strongly encouraged. In the meantime, continued research support is endorsed to capitalize on the prospects for solving difficult technical requirements by the use of this unique metal.

Background, References and Correspondence

Rare Metals Handbook, 2nd Edition 1961, Clifford A. Hampel, Reinhold Publishing Company.

Report of the Committee on Refractory Metals, Materials Advisory Board, MAB 154-M(1), October 15, 1959.

Rhenium, edited by B. W. Gonser, Elsevier Publishing Company, 1962.

U. S. Bureau of Mines, "Commodity Data Summaries," January 1968.

Helpful information was provided in correspondence from Dr. E. Hayes, U. S. Bureau of Mines; J. Maltz, NASA Headquarters; Dr. R. J. Lund, Battelle Memorial Institute; J. W. Spelman, Cleveland Refractory Metals; J. A. McGurty, General Electric Company; and F. W. Foyle, Rhenium Alloys, Inc.

APPENDIX A

Resolution approved by the NASA Research and Technology Advisory Subcommittee
on October 24, 1968

Whereas the ductilizing effect of rhenium additions in the Group VIA metals has served to focus direct attention to the interrelationship between the electronic structure and gross mechanical properties of metals and, Whereas it now becomes apparent that similar interrelationships underlie a multitude of important technological problems, such as refractory metal ductility and stress corrosion cracking,

Therefore, the Research and Technology Subcommittee recommends that research to link the electronic structure with the mechanical properties of metals and alloys be encouraged.

Specific examples of this recommended research activity as related to the rhenium effect include:

- 1) Bond structure characterization in the W-Re system.
- 2) Heterogeneous nucleation studies in the W-Re system (dislocation-solution interactions).

General examples of this recommended research as related to a diversity of problems include:

- 1) The development of ultra high resolution techniques for detailed study of structures in metals and alloys.
- 2) Systematic investigation of the mechanical properties of alloy systems with readily characterizable electronic structures.
- 3) Calculations of mechanical properties based on crystal physics.

The Subcommittee further recommends that the Materials Advisory Board, the NASA laboratories and the university interdisciplinary laboratories (NASA, ARPA, and AEC) explore this activity, and that this program area be reviewed periodically by this Subcommittee.

APPENDIX B

Conclusions and Recommendations Report of the Raw Material Group, Panel on Rhenium

1. Immediate consideration be given to the establishment of a Government purchasing program, to encourage the recovery of rhenium and provide a stockpile for technical use, so that as much as possible of the known one million pounds of economically recoverable rhenium of the world shall be conserved.

The preferred stockpile material should be pure ammonium perrhenate, NH_4ReO_4 . This compound is readily convertible to other compounds of rhenium and to metallic sponge, and can be prepared virtually free of potassium, which even in small amounts produces inferior rhenium metal.

The technology for the recovery of rhenium is sufficiently developed that recovery and delivery of ammonium perrhenate by industry could be initiated within a very short time from waste products, provided that an attractive dependable market for the product were provided.

The lack of a reserve of source material is a serious deterrent in the development of uses for this unusual metal. Industry cannot be expected to spend large sums to develop uses for a material when no supply for production exists.

The United States has the principal known sources of rhenium. It should be conserved for our own future strategic and special economic uses. Chile, a free-world country, is another important potential long-range producer.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Materials Advisory Board Committee on Technical Aspects of Critical & Strategic Materials		2a. REPORT SECURITY CLASSIFICATION Unclassified	
3. REPORT TITLE TRENDS IN USAGE OF RHENIUM		2b. GROUP	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Annual Report			
5. AUTHOR(S) (First name, middle initial, last name) Materials Advisory Board Committee on Technical Aspects of Critical & Strategic Materials			
6. REPORT DATE December 1968		7a. TOTAL NO. OF PAGES 9	7b. NO. OF REFS 5
8a. CONTRACT OR GRANT NO. DA-49-083 OSA 3131		8b. ORIGINATOR'S REPORT NUMBER(S) MAB-251	
A. PROJECT NO. C. d.		8c. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10. DISTRIBUTION STATEMENT This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Office of the Director of Defense Research & Engineering (Chief Matls. Div. OADCT).			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Department of Defense	
13. ABSTRACT Rhenium is a rare, expensive, high-melting metal with some unique properties, including a ductilizing effect on several brittle refractory metals. It occurs as an impurity in molybdenite which is associated, in small amounts, with copper ores. Production and consumption have been less than a ton per year, with the potential production, while substantially larger, still definitely limited. Research is disclosing probable valuable applications, leading to the recommendation that efforts to conserve rhenium for probable future applications should receive support.			

DD FORM 1 NOV 65 1473

Unclassified

Security Classification

Unclassified

Security Classification

14.	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	Rhenium Supply Applications Substitution Stockpile						

Unclassified

Security Classification